

CANDID VOICES

Agile Combat Support From the OC-ALC Engine Shop Viewpoint

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Introduction

Force drawdowns, lean logistics processes, base realignment and closures, Agile Combat Support—these are just a few of the recent initiatives focused on posturing the military for the 21st Century. This article takes a look at some of the effects of these and other Air Force logistics initiatives on engine repair processes taking place on the depot's shop floor. This article will take the Agile Combat Support initiative¹—the focus of combat support shifts from maintaining massive inventories to establishing a response capability—as the goal and will focus on the changes happening/required on the engine shop floor at Oklahoma City Air Logistics Center (OC-ALC) to make that concept a reality.

Background

The Propulsion Directorate, OC-ALC, is tasked with the worldwide management of many of the Air Force's turbine engines. Within this Directorate, the Propulsion Production Division manages the repair and overhaul of over 700 engines

and nearly 1.2 million repair hours of engine components annually.

This engine repair/overhaul process falls within what is defined as a *reparable-item inventory system*. A reparable-item inventory system is a system used for controlling items that are generally very expensive and have long acquisition lead times.² Hence, it is more economical to design these items so they are repaired after they fail, rather than treating them as consumable items which are disposed of after use. A standard military reparable-item inventory system consists of a repair facility (depot) dedicated to support several locations (bases) dispersed over an extensive geographical region where equipment (aircraft) is assigned. Over time, equipment malfunctions occur due to the failure of a specific item (engines or engine components) internal to the equipment. A corresponding serviceable item is then obtained from an inventory location and installed on the malfunctioning equipment, thereby restoring it to full operational capability. The failed item is tracked as it is shipped to the repair facility, scheduled for repair and subsequently shipped in a serviceable condition back to an inventory location.³

The Propulsion Production Division has two branches that

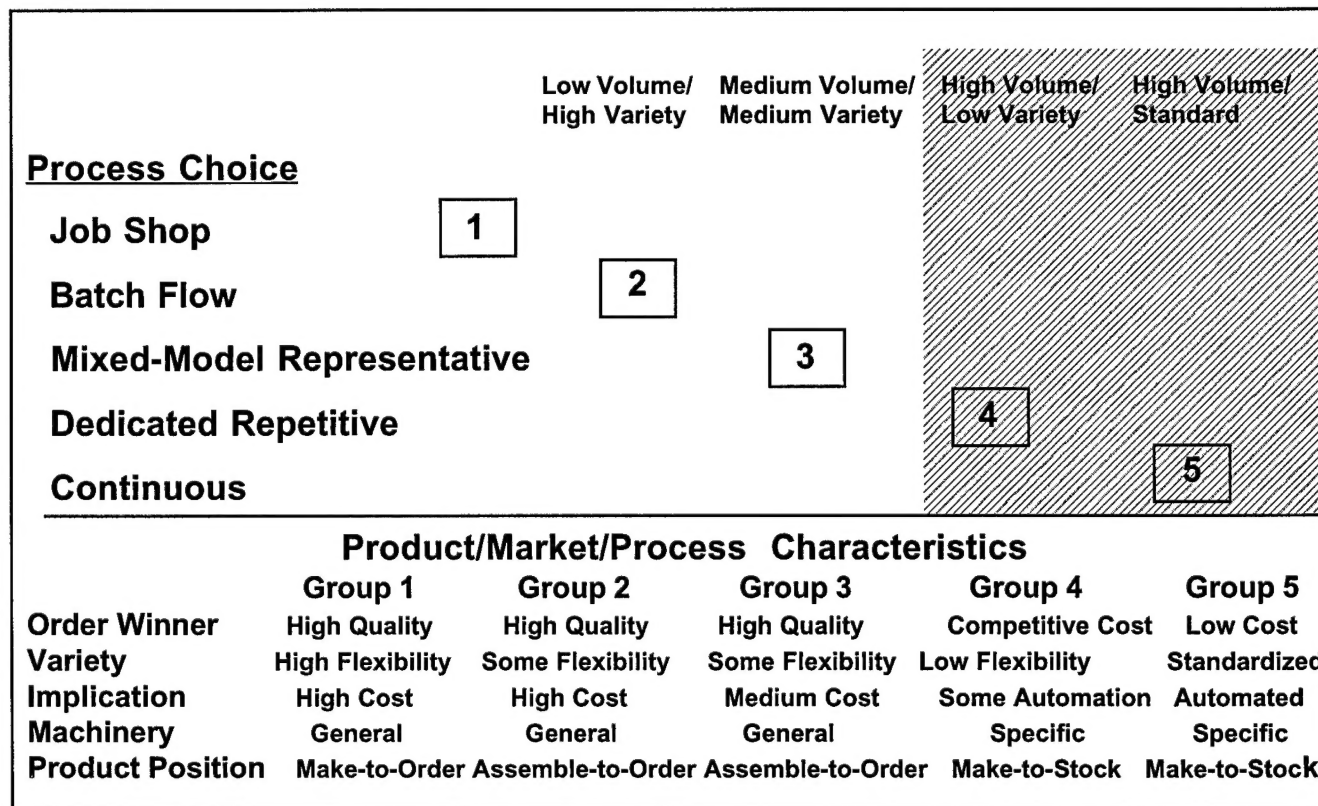


Figure 1. Make-to-Stock Structure

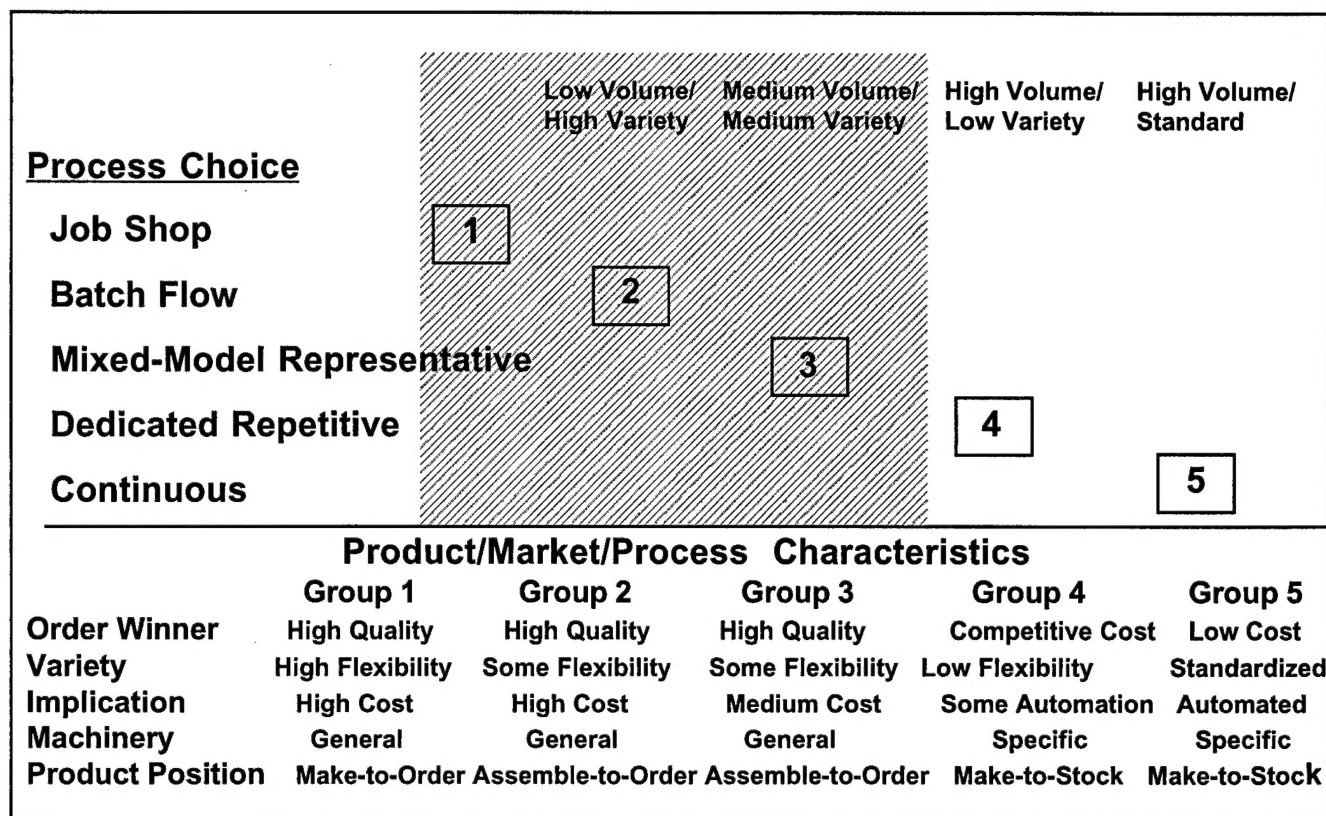


Figure 2. Make-to-Order Structure

perform the repair functions of a reparable-item inventory system for engines and engine components. For simplicity, they will be referred to as the front-shop (whole engine assembly and disassembly) and the back-shop (component repair). The front-shop supports worldwide turbine engine repair. The back-shop has two customers—they provide engine components to the front-shop (engine assembly line) to produce whole-up engines and they provide engine components to the bases that have the ability to remove and replace these components (line replaceable units—LRUs) in the field. The Propulsion Directorate at OC-ALC has been a part of this reparable-item inventory system for turbine engines for more than 40 years, but the pressures to adapt to changing environments, strategies, competitive pressures and economic situations have never been stronger than they are today.

The Initiative—to Be Responsive, Flexible and Precise

Agile Combat Support pushes the Air Force to develop logistics systems that are responsive, flexible and precise. Lean Logistics (now termed Agile Logistics), drawdowns, reduced budgets and other fiscal constraints require the Air Force to reduce infrastructure, maintain smaller numbers of both inventory and personnel and find ways to reduce costs. All these initiatives have a common desired result: to execute the initiative and to achieve the associated benefits—without degrading mission capability.⁴ They also have some inherent conflicts when they are simultaneously applied to the depot repair process.

Responsiveness

To our customer, a responsive logistics system will have

the parts (engines) needed available at the exact time they are required. In the past, this was accomplished by having ample stocks of parts located at each and every base around the world. In production management terminology, the depot operated as a *make-to-stock* organization (shaded area in Figure 1).⁵ Depots supported this *make-to-stock* inventory policy by producing to a quarterly and annual schedule that was developed based on historical usage and flying hour forecasts. This allowed the depot shop floor to operate on a balanced schedule—a modified continuous/repetitive manufacturing process—throughout the year. This balanced schedule was important since the logistics (parts support) and resource (personnel and budget) processes that support the production efforts were also developed to support a balanced schedule.

In 1994, the Air Force developed the Lean Logistics (now Agile Logistics) concept in response to fiscal constraints and force drawdowns. Under this concept, the method to achieve a responsive logistics system changed. Instead of using large stocks of spares to meet the customers needs, the Air Force moved towards shortening the logistics pipeline via fast transport and shorter field and depot processes. This forced the depot to operate more like a *make-to-order, assemble-to-order*, (shaded area in Figure 2) or *Just-In-Time* manufacturing organization. The ability of a depot to respond quickly to changing needs in the field had to be developed to support the Lean (now Agile) Logistics and Agile Combat Support initiatives.

The need to be responsive on the depot shop floor has driven many changes. For example, in the past, an engine or engine

component that was sent to the depot for overhaul would be brought back to a *like-new* condition. In many cases, the depot repair process would repair and/or replace items that did not need to be repaired/replaced. This was inefficient as it wasted parts, manpower and increased depot flow time for both the front-shop and the back-shop. The answer to this inefficiency was to perform a greater amount of *on-condition* maintenance. Under this concept, an engine or engine component entering the depot repair process undergoes a workscope inspection prior to overhaul. This workscope inspection determines the minimum required repairs necessary to return a depot-overhauled engine or engine component with a specified life cycle to the user in the field. The result of this change shortened the flow time for repair of both engines and engine components and allowed the depot to provide more responsive support to the customer.

Another example of change brought about by the need to be responsive is the method and quantity of items brought into the depot for repair. As mentioned before, depot shops in the past produced to both quarterly and annual schedules, with the goal to be as efficient as possible. This created a system where large batch sizes of similar parts were pushed through the repair process at one time—large batch sizes reduced the number of setups required in each shop and returned excellent output numbers per man-hour (efficiency). However, there was no correlation between what was being repaired in the depot and customer needs.⁶ The depot was producing according to schedule and its performance metrics were excellent, but it was not responding to the customer. Under the Depot Repair Enhancement Program (DREP), this concept changed. Now, the engine shops at the depot

respond directly to customer needs—inducting and repairing individual items according to the greatest need in the field.

At no time in history can the engine and engine component repair process be described as a pure assembly line or continuous/repetitive manufacturing process; however, on a continuum like that shown in Figure 3, the push to a more responsive, flexible system has moved the shop floor process further away from the continuous/repetitive manufacturing system and toward a *job-shop* type environment. A continuous/repetitive manufacturing environment, while generally considered the most efficient form of production, does not respond well to changing requirements. Henry Ford's assembly line is often used as an example of this, where he offered his vehicles in three colors; black, black and black. He did this because of the lack of responsiveness and flexibility inherent in his manufacturing process. A job-shop type environment, on the other hand, is more flexible and can respond to needs for a wide variety of products. However, it is here where a conflict between Agile Combat Support and Agile Logistics appears. Yes, the job-shop environment is more responsive, but it also requires a higher amount of work-in-process inventory to buffer variations in work center loads that are caused by variations in product mix.⁷ It is those inventories the original Lean Logistics initiative eliminated. Today, on the shop floor, the reduction in work-in-process inventories along with the rise in unavailability of bit-and-piece parts required to repair engines and engine components is the biggest challenge facing shop managers and depot production.

One of the reasons this lack of inventory is hindering

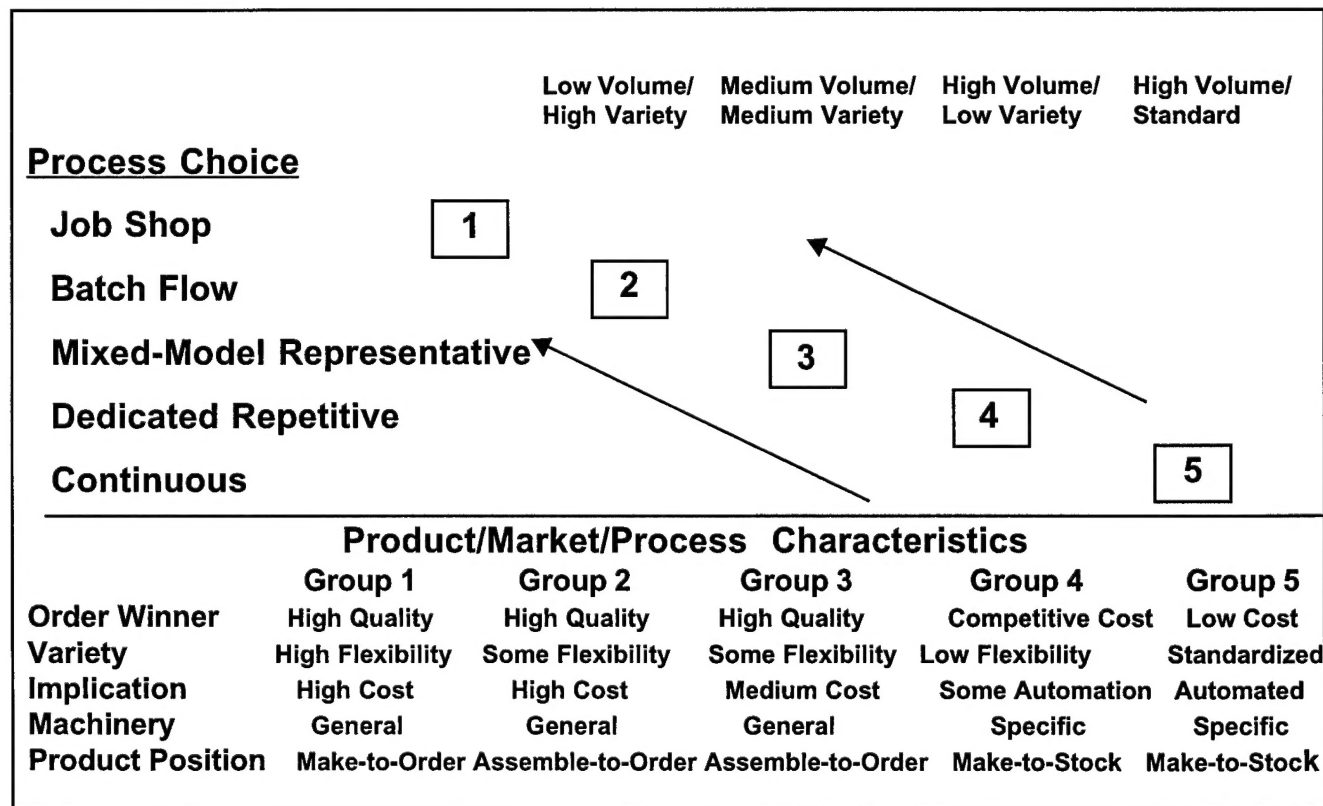


Figure 3. Item Repair Based on Greatest Needs of Job-Shop Structure

production is because in the past the depot shop floor had excess inventory that masked process problems with ordering, tracking and prioritizing procedures. When the inventory levels declined, the true process problems began to appear. The DREP program is attacking these problems by developing integrated support teams (shop service centers) to effectively manage materiel ordering, tracking and support. It is the shop service center's responsibility, as we move into demand-driven induction for repair, to develop and manage the inventory processes necessary to support production.

Supportability has been hindered by another factor: variability. The push for responsiveness has created higher levels of variation in the process by inducting assets based on customer

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demand/need as opposed to a balanced quarterly or annual schedule. The push for less waste through increased on-condition maintenance has changed the demand for many parts from being dependent to independent. Where the demand for dependent parts can be determined from its parent item (where an engine always needs the same parts to be rebuilt), independent demand such as repair-type items (on-condition maintenance) can only be forecasted—and mainly by projecting requirements based on historical demand patterns (replacement factors).⁸ The increased variability caused by demand-based induction in today's unpredictable world is in direct conflict with an increased reliance on forecasting of independent demand items. To resolve this conflict, a number of initiatives are in work. Supply management policies have changed to shorten resupply times for expendable items managed by the Defense Logistics Agency (DLA). This system parameter design reduces the amount of stock on-hand and replaces it with resupply velocity. It does this by automatically ordering on a one-for-one basis each time an item is issued, which feeds data to DLA that results in better buy practices and shorter resupply times. Other initiatives, such as establishing closer relationships with DLA and other suppliers, reducing acquisition lead times and redefining bench stock (indirect expendable materiel) policies are ongoing to allow production management to find the middle ground between low levels of inventory and the ability to deal with variability in the production process—the solution that will allow production to be responsive to the customers' needs.

Flexibility

To be responsive to the customers' needs, especially in the current environment filled with variability, the manufacturing process must be flexible. The depot shop floor must be able to produce an engine for a F-16 fighter and a KC-135R tanker simultaneously. That will require the back-shops to repair all the reparable components for a single General Electric engine at

the same time it is repairing all the reparable components for a single Pratt & Whitney engine. The move toward a job-shop manufacturing environment in itself adds the required flexibility to the manufacturing process through the use of flexible, general purpose equipment that can be used to produce a wide variety of products.⁹ Alternate routings through a repair process, multi-skilled employees, shorter setup and repair times, to name a few, are additional methods to improve process flexibility and are central points of focus for engine shop floor managers and process engineers. However, the supporting resource systems must also be flexible to provide support to the manufacturing system.

Manpower resources, for example, must be flexible to allow the manufacturing system to be flexible. Under the depot environment where production was based on quarterly and annual schedules, workload was balanced for the fiscal year. Direct labor personnel levels were determined based on the

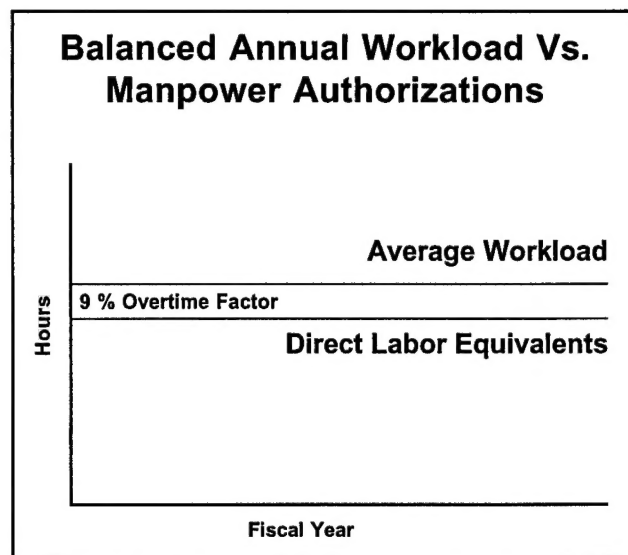


Figure 4. Direct Labor Personnel Levels—Average Workload

average level of work on the shop floor for the year (Figure 4). As long as workload stayed constant at the average determined at the beginning of the year, the shop floor had the personnel needed to meet its schedule. Any minor levels of workload variance that required additional output would be handled by the use of overtime. This worked well because it resulted in a smooth level of operation that avoided the costs of changing production levels. A drawback to this is the possibility that inventory would build during low demand periods since the shop was building to schedule, not to customer needs. Or, because the shops had personnel available to do the work and the need to meet efficiency targets, they would continue to produce items that were not needed.¹⁰ Prior to the Lean Logistics initiative, the over-produced parts would go to stock, to meet a future need.

Today, personnel levels are still determined based on the average workload for the year. Therefore, any variation in workload (which we have intentionally added to the process to create a responsive organization) creates personnel management problems on the shop floor. The challenge, then, is to meet additional production, when needed, without using excessive overtime labor and to avoid building inventory during periods

Variable Workload Vs. Manpower Authorizations

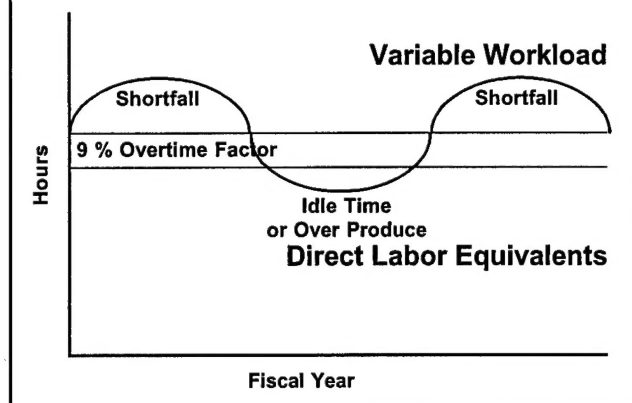


Figure 5. Direct Labor Personnel Levels—Variable Workload

of low customer demand (Figure 5). Clearly, a stable manpower policy does not promote flexibility on the shop floor.

Another problem exists when you combine the following three factors: (1) variability created by demand-based induction of items for repair; (2) the policy of using an average annual workload to determine manpower; and (3) the fact that available shop capacity is approaching required shop capacity (the OC-ALC ratio is 93 percent). This can result in production queuing, climbing work-in-process inventories and poor production output—directly in conflict with the Agile Logistics initiative.¹¹ The answer: process engineers and workload managers continue to reduce flow days through process improvements, setup reductions and variable repair process routings—freeing up or using existing capacity to its maximum potential. Alternatives for capacity, such as teaming and outsourcing, are being pursued and used when economical to do so.

Precision

From the customer perspective, *precision* from the depot can mean a number of different things. Two important factors from this viewpoint are: (1) meeting the customers' needs on-time and (2) producing a quality product. In both cases, DREP and other changes on the shop floor, to include upgraded information technology systems and quality programs, are being deployed to improve operations to provide this *precision*.

Produce to Need and on Time. As mentioned earlier, the DREP concept was developed, in part, because of the mismatch between depot production and customer requirements. Depot production, to be responsive to the customer, needed a method to identify true customer requirements and a repair policy based on those requirements. Under DREP, these needs were addressed and supported by an automated system called the Execution and Prioritization of Repair Support System (EXPRESS). This system was designed to identify customer needs, prioritize needs for repair and distribution, assess repair supportability and identify constraints and to trigger automatic introduction of reparable

into repair.¹² EXPRESS, along with the Air Force's Readiness Based Levels (RBL) program, addressed the proper identification of customer needs and the depot repair of those needs in priority sequence.

EXPRESS is in use on the engine component repair shop floor (back-shop) and has brought improved visibility of customer requirements and their associated priorities. However, EXPRESS does not handle all the complexities of the engine repair process; therefore, it does not provide complete utility to the engine world as it does to the shops in which it was tested/prototyped (avionics). For example, EXPRESS does not provide total visibility for all engine customer requirements. Parts routed to the back-shop from the front-shop, aircraft Programmed Depot Maintenance (PDM)/Standard Depot Level Maintenance (SDLM) requirements and Navy workload are repair requirements that are not visible to EXPRESS. Because of this, shop workload managers have to manually apportion their capacity to support EXPRESS driven and non-EXPRESS driven requirements. Also, these workload managers find the challenge of balancing conflicting priorities between the EXPRESS driven and non-EXPRESS driven requirements (which top-priority item to repair first?). The impact of having two separate systems on the shop floor: increased complexity. Air Force Materiel Command (AFMC) and others are working to resolve these problems by adapting EXPRESS to handle the other requirements or by adapting the other requirements to fit into EXPRESS. Even with this shortfall, however, EXPRESS has improved the visibility of customer needs and provided the induction-on-demand method needed to produce to customer needs.

Once the needs are identified and items are inducted for repair, production management must provide the output on time. The time concept, in today's Just-In-Time environment, adds yet more complexity to the shop floor. Remember, in the past, the engine shops produced to schedule, with the goal of having items sitting on the shelf when they are needed. Metrics focused on output, and the prior management philosophy was *push enough engines and parts in the north end of this building, and I'll get what you need out the south*. This mentality was well suited with the continuous/repetitive manufacturing environment that used to exist. Today, however, the job-shop environment, combined with a constrained pipeline, requires shop floor managers to produce the limited amount of assets in the pipeline on time (induct only on demand, then output per scheduled flow days of repair). Complicated repair routes and the problems with parts supportability further challenge the shop floor managers to provide the required output on time. To measure success, new metrics are being developed that will focus on both input and output and will be detailed to the point of tracking each step in a repair process (queue, setup, run, wait and move times for each step). These new metrics will allow the shop floor managers to more efficiently manage their processes and bring improved *precision* to the shop floor.

To support the new metrics, the Production Branch at OC-ALC is looking at Information Technology (IT) improvements to provide the required information. The Inventory Tracking System (ITS) at OC-ALC has the capability to track and time each

repair part through each part of the repair process. Currently, it is used to track total flow times for repair, but recommended changes to improve usability and the addition of improved input media such as radio-frequency bar code readers will allow shop floor managers to capture data relating to each step in the repair process. These improvements are funded and should be implemented in the near future. In a related IT project, research into shop-floor scheduling tools is underway to fill the gap that exists between the induction process handled by EXPRESS and the subsequent scheduling of flow through the repair process. EXPRESS drives the requirement into the first repair shop in a process. Any subsequent shop that the part flows through, however, is not viewed within EXPRESS for capacity or supportability. When the parts flow through these secondary back-shops, they are handled on a first-in, first-out (FIFO) basis. FIFO, as a scheduling tool, does not perform well in an environment where performance to schedule is important¹³—it is detrimental to the goal of precision. A prototype of a scheduling system built over a simulation of the repair process exists in the avionics arena here at OC-ALC, and it looks like it could be the model for a scheduling system for engine repair. Until an automated system can be made available, managers are looking at policies such as *earliest due date* or a theory of constraints type (drum-buffer-rope) system to use in place of the FIFO system. These tools (improved metrics and a better scheduling policy) are necessary for the shop floor to achieve the needed level of precision to effectively manage the complex engine repair processes.

Quality. If the customer does not receive a quality product, all efforts to produce to need and on time are valueless. Producing a quality product, especially in the turbine engine production arena, has always been of extreme importance—mainly due to engine-related safety-of-flight concerns. Under the Agile Combat Support initiative, quality concepts change in that they must protect the limited quantity of assets in the pipeline. End-item quality has always been important—totally eliminating defects anywhere in the process is the focus for the future. Quality programs are focusing more on repair processes than on just end-item inspections with the intent of designing quality into the product and the process.

At OC-ALC, engine quality has been a success story. Engine component quality, from the customer viewpoint, has met needs for form, fit and function 99 percent of the time. Whole-engines pass end-item inspection at an 88 percent rate, but more importantly, this rate shows a trend of continual improvement over the last three years. Current quality improvement programs and emphasis on foreign object damage prevention are intended to continue the positive trend. Additionally, current quality program efforts include the push to become ISO 9000 compliant. ISO 9000 is an international quality systems standard that provides guidance in the development and implementation of an effective quality management system.

Closing

The changes required on the depot shop floor for Agile Combat Support are significant. We have added a great deal of complexity to the processes and have asked a declining (in numbers) workforce to perform in this new complex environment. In many cases, programs such as DREP and Information

Technology improvements have the shop floor moving in the correct direction. These tools, when fully implemented, will help shop floor production managers better deal with the added complexities of Agile Combat Support. In other cases, the shop floor is facing factors beyond its control in its attempt to be responsive, flexible and precise. Other groups, at HQ AFMC and elsewhere, have taken the lead to provide these needed improvements. This article attempted to point out examples of both. Nevertheless, on the shop floor, significant progress is being made. Even in the commercial world, changes to Just-In-Time or other customer-oriented manufacturing environments take a great deal of time to successfully implement—some companies plan this to take six years or longer.¹⁴ Is it worth the time and effort to make these changes on the shop floor? Yes. The depot process, in the engine production arena, has always produced a quality product for its customer and saves a significant amount of taxpayer money. When looking at only seven of the 692 active repairs occurring on the engine shop floor, the ability to repair versus replace saved nearly \$8M in Fiscal Year 97. Future improvements, to bolster Agile Combat Support, will produce future savings by providing a more responsive, flexible and precise process by providing high velocity, high quality logistics support to the warfighter and by providing readiness capability should it be needed.

Notes

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